Commercial Supersonics Technology Project—Status of Airport Noise

Presented at Acoustics TWG, Langley Research Center

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Overview

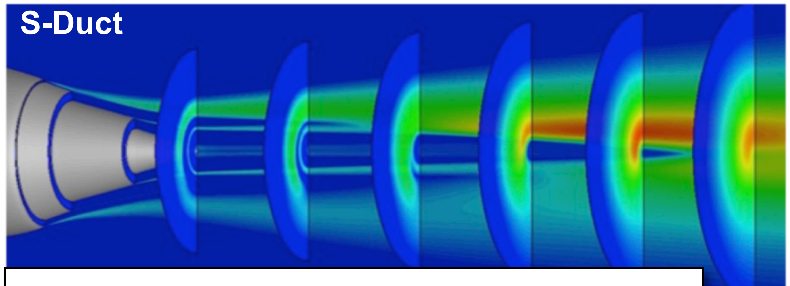
- Project Maturation
  - Spinoff of QueSST
  - Low-Noise Propulsion (LNP) Tech Challenge due 30 Sept 2016
- Tech Development for LNP Tech Challenge
  - Evolution of VCE system studies
  - Exploration of low-noise nozzles for VCE
  - Modeling and prediction tool development
  - Validating current best solutions
- Looking Ahead

CST Project Maturation

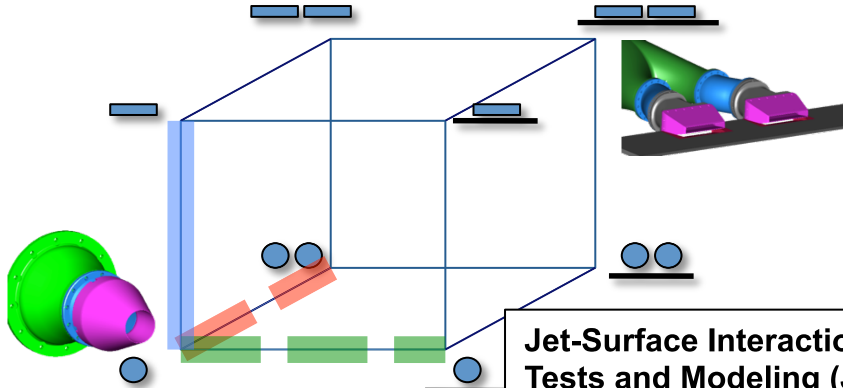
- QueSST
  - The single-pilot X-plane to mimic sonic boom of commercial airliner
- Goals:
  - Demonstrate design prowess for low-boom design with real-world complications
  - Allow testing of community response to guide regulations for certification

Low-Noise Propulsion Tech Challenge 2016

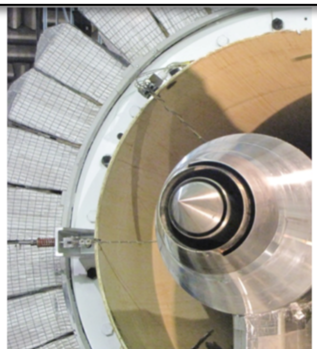
- **Supported by years of research:**



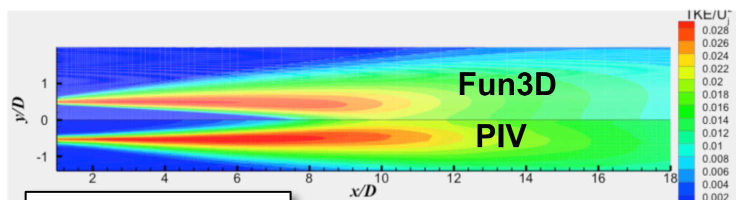
3-Stream, Externally Mixed, Offset Streams



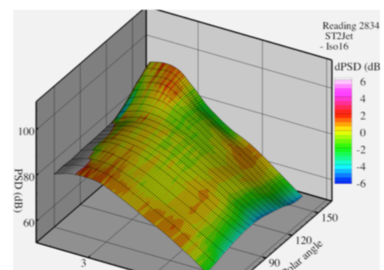
Jet-Surface Interaction Tests and Modeling (JSI)



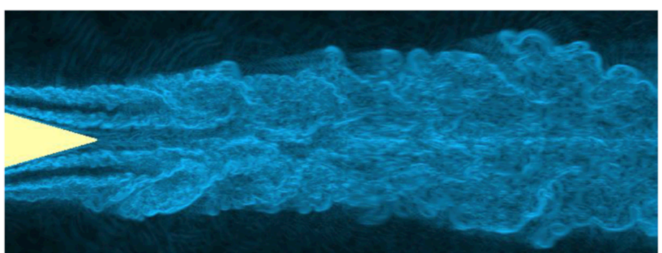
Inverted Velocity Profile



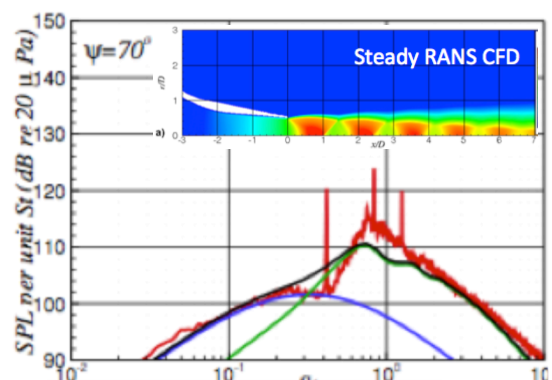
CFD validation



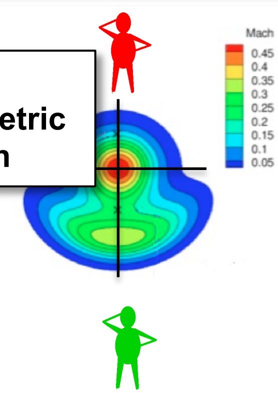
Empirical Modeling (TSS)



LES validation



RISN Acoustic Analogy



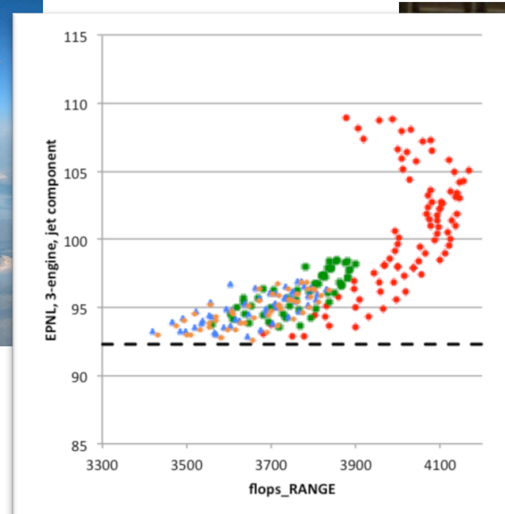
Non-axisymmetric Green F'n

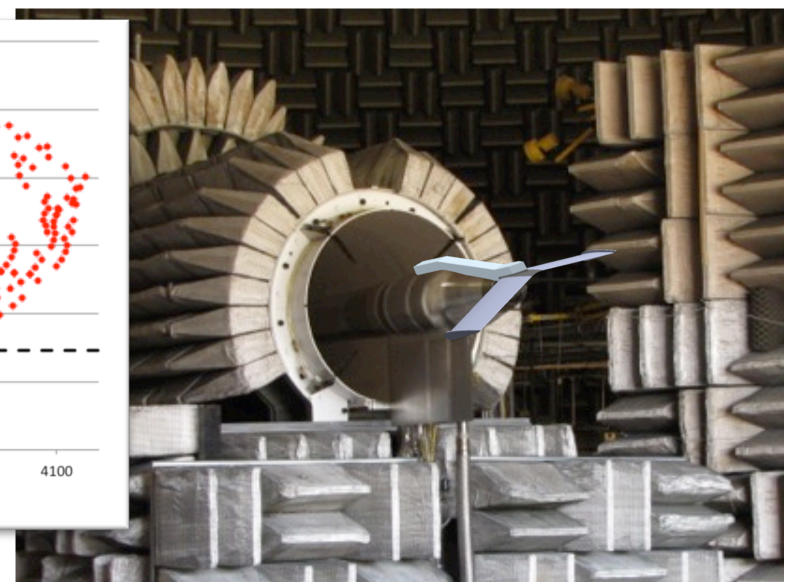
Level 1 Milestone

- CST1.1.02.L1: Low Noise Propulsion for Low Boom Aircraft
- **Exit Criteria:** Design tools and innovative concepts for integrated supersonic propulsion systems with noise levels of 10 EPNdB less than FAR 36 Stage 4 demonstrated in ground test.

- Based on Lockheed-Martin 1044 airframe (L/D, cruise, boom)
- Explore propulsion cycle/nozzle options; focus on installed exhaust noise
- Validate in scaled model test with simulated planform


LM1044 N+2 vehicle





Design Tools

- Empirical Codes
  - Creation of NPSS engine model, ModelCenter aero model
  - Developed & validated TSS code to predict noise of many VCE nozzles
  - Developed & validated JSI code to predict acoustic impact of installation
  - Integration of models with ModelCenter system optimizer ongoing
  - **Used to design low-noise/low-boom vehicle, final Tech Challenge configs**
- RANS-based Acoustic Analogies
  - Developed non-axisymmetric Green's function
  - Developed hot jet source models
  - Qualified several RANS codes (Wind US, FUN3D, FloEFD)
  - Quantitatively apply to isolated nozzles and qualitatively to installed propulsion
  - **Primarily used for design guidance, insight (relative noise prediction)**
- Large Eddy Simulations
  - Supported external community of developers (academic, SBIR, industry)
  - Explored spectrum of schemes from URANS to LES for noise capability
  - Making NRL's JENRE code operational at NASA
  - **Primarily used to diagnose unexpected resonance phenomena**

Innovative Concepts

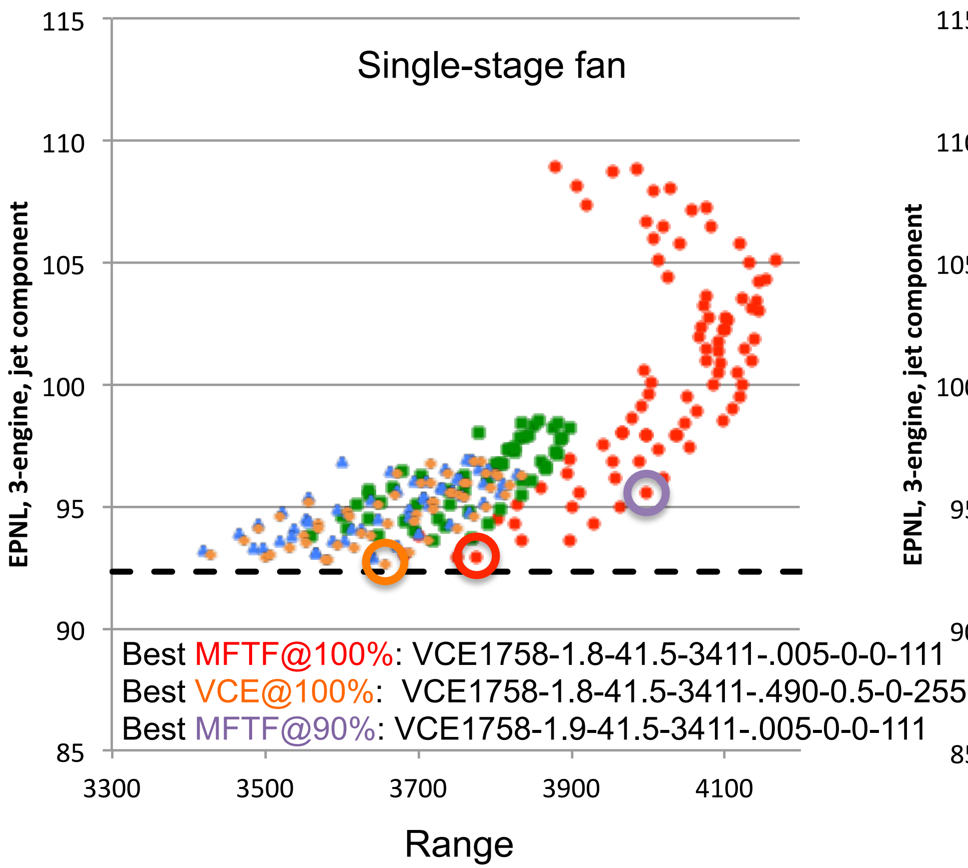
- Variable Cycle Engine (VCE)
  - Innovative variable cycle architecture based on DoD investment
  - Variable specific thrust attractive for higher BPR at airport, lower BPR at cruise
  - In-house and industry exploration. In-house designs used for Tech Challenge
  - Compare against state of art mixed flow turbofan (MFTF)
- Multiple nozzle concepts explored
  - Externally mixed nozzles
  - Offset stream tertiary nozzle
  - Inverted velocity profile (IVP)
  - Buffer flow on IVP
  - Mixer-ejector
- Impact of installations explored
  - Benefit of shielding/Cost of reflection
  - Jet-by-jet shielding
- Optimization of cycle vs range vs sonic boom

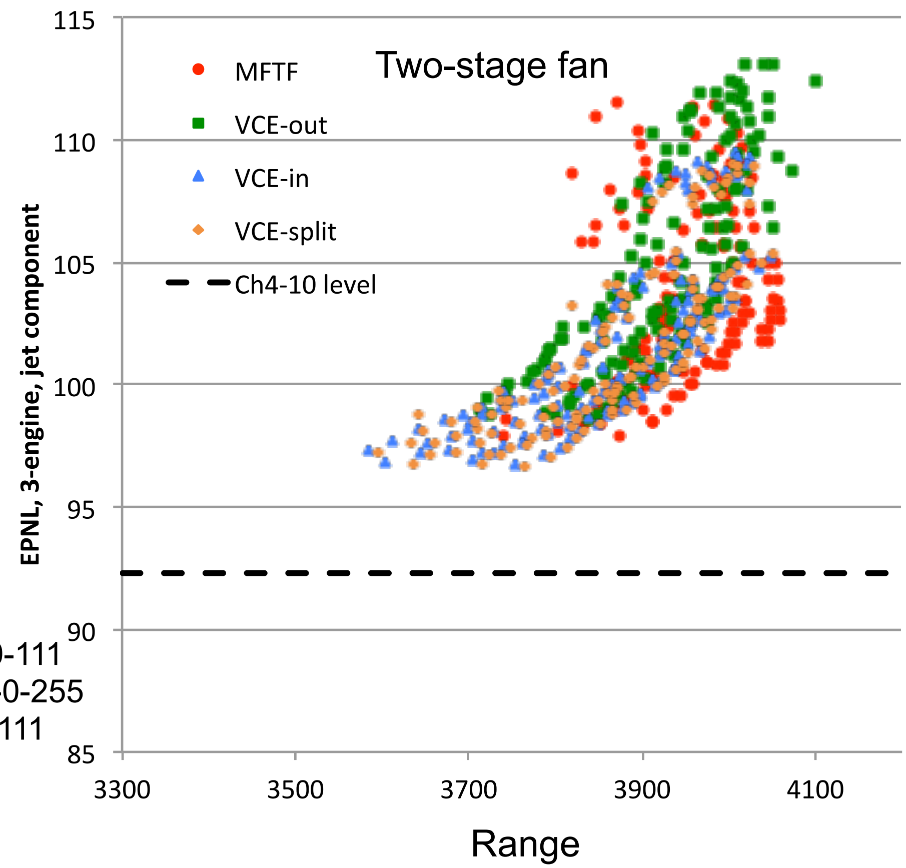
10dB below Stage 4

- Assume exhaust noise dominates at Lateral (sideline) certification point, not significant at Approach point
- FAR Part 36 **Chapter 3** requires **99.3EPNdB** max at lateral for LM1044 airliner. Chapter 4 is 10dB (cumulative), with reduction at all points.
- Assuming that Approach is not dominated by exhaust noise, split remainder between Lateral and Flyover points.
  - Ch4 would require Lateral to be 95.3EPNdB.
  - Ch4 – 10 would require Lateral to be 92.3EPNdB
- **Ch4–10dB** equates to **92EPNdB** for the Lateral observer with an installed three-engine exhaust system

Engine Design

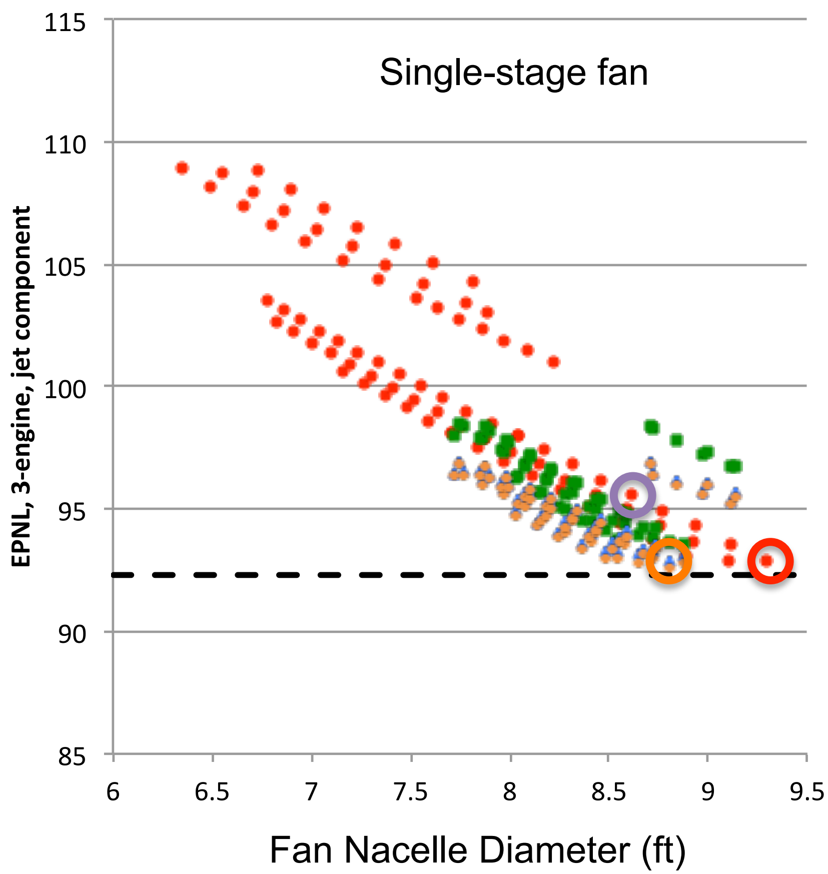
- Engine model exercised using design variables: # fan stages, nozzle type, FPR, BPR, T4
- Output lateral noise EPNL, range, engine diameter, emissions index
- Pick off designs that meet noise goal with and without PLR.

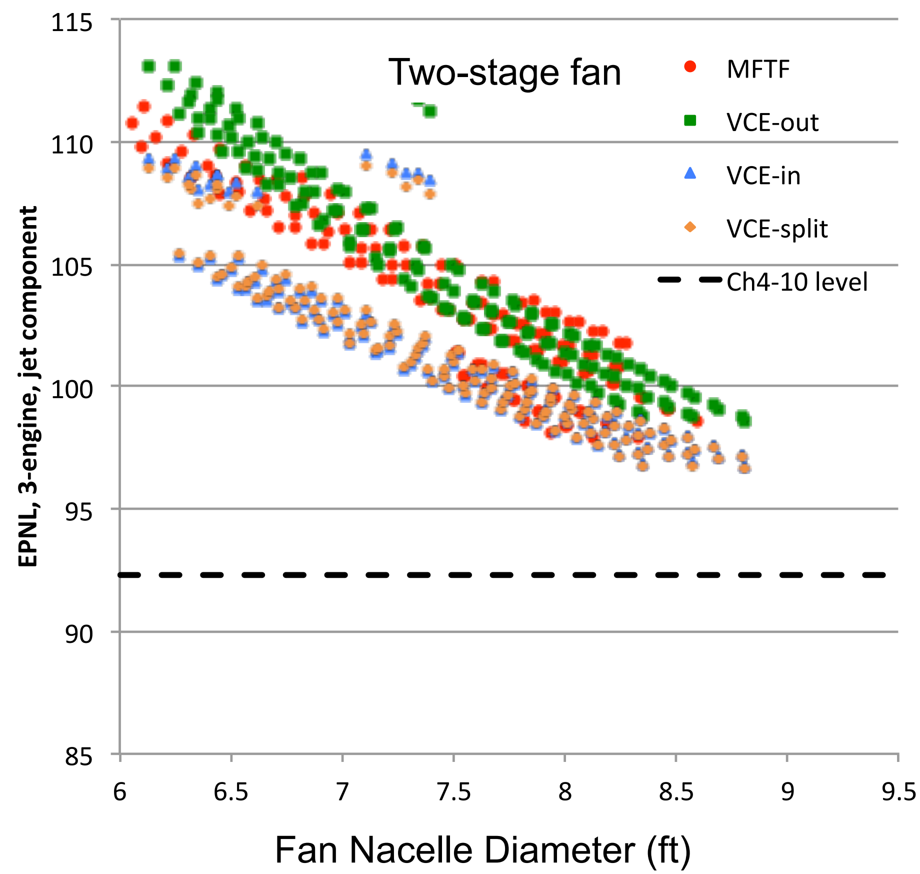




Noise vs Nacelle Diameter

- Engine diameter quantitatively impacts Range
- Engine diameter is soft limiter on sonic boom
  - At some point small adjustments cannot compensate

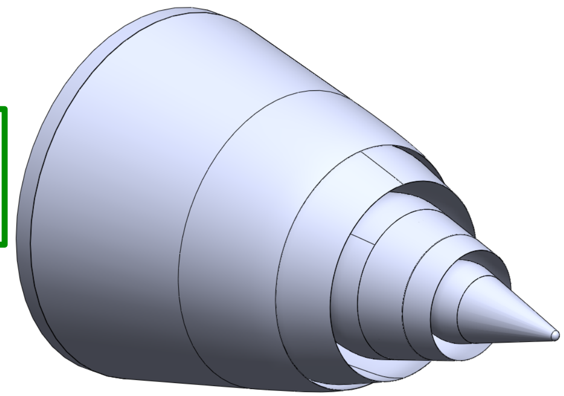


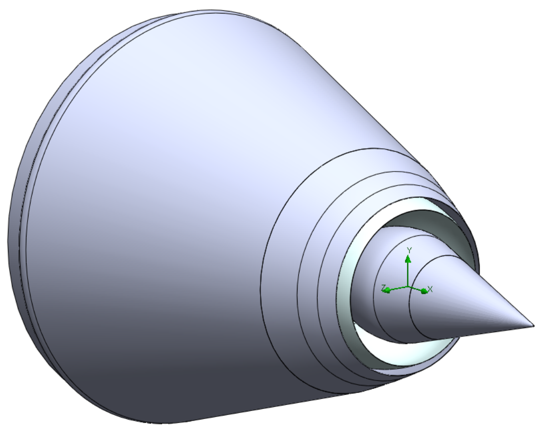


Validation of Empirical Models for VCE Nozzles

- Candidate nozzles from Isolated Nozzle Test (Iso16)

Externally mixed core, fan, tip flows

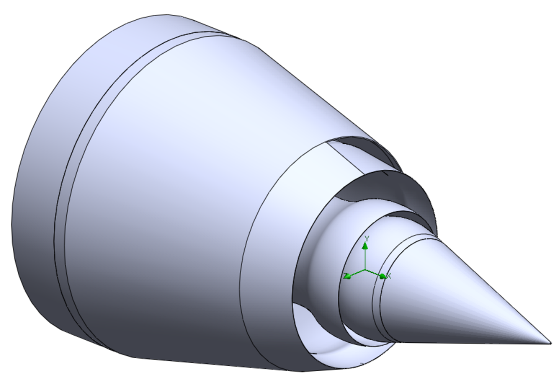




Internally mixed core & fan, conventional tipflow

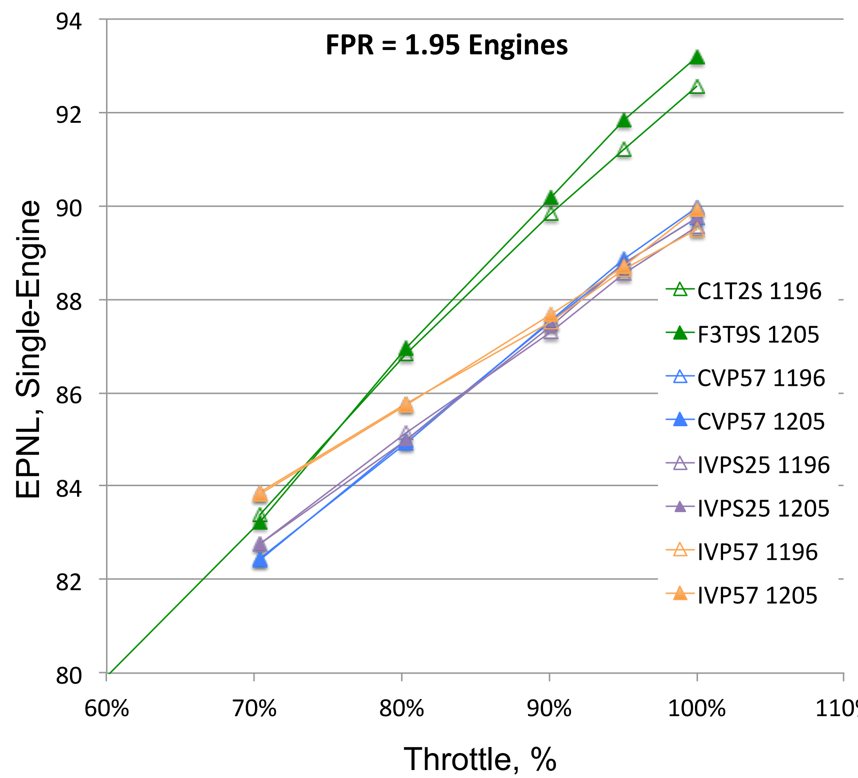
Internally mixed core & fan, inverted tip flow

Optional; split tip flow to outer buffer



Impact of Nozzle Types on VCE engines

- Given cycle that gets close to target, compare impact of nozzle type
- ENPL vs throttle for two FPR = 1.9 engines (differ in BPR), different nozzle types in color
  - IVP, CVP nozzles make same noise at full throttle; IVP diverges at low throttle
  - Externally mixed is louder at full throttle; joins internally mixed nozzles at lowest throttle
  - Bypass ratio relatively unimportant



Setpoint	At/Ap	Ab/Ac	At/Ac	(Ab+At)/Ac
1196	0.53	1.78	1.52	3.30
1205	0.53	1.33	1.26	2.59

VCE vs MFTF

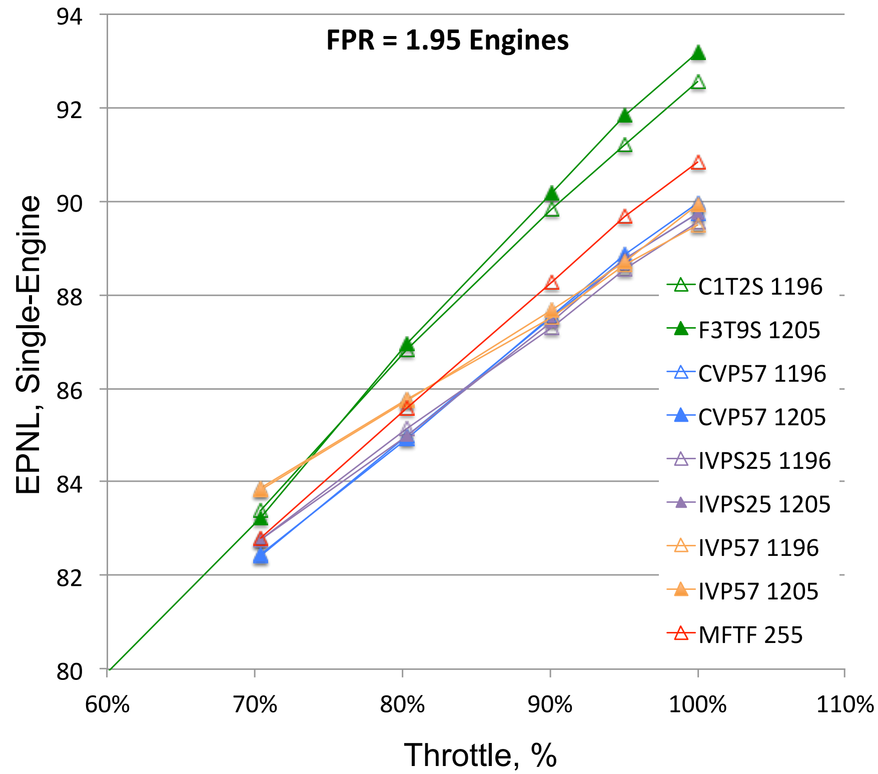
- Compare MFTF at FPR = 1.95
- Add MFTF engine/nozzle at same FPR

Compared to VCE with IVP or CVP nozzle:

- MFTF is EPNdB louder than IVP/CVP
- MFTF gains 50nmi
- MFTF is 6% larger diameter

Final integrated test:

- IVP and IVPS on three VCE engines cycles
- MFTF on two engine cycles

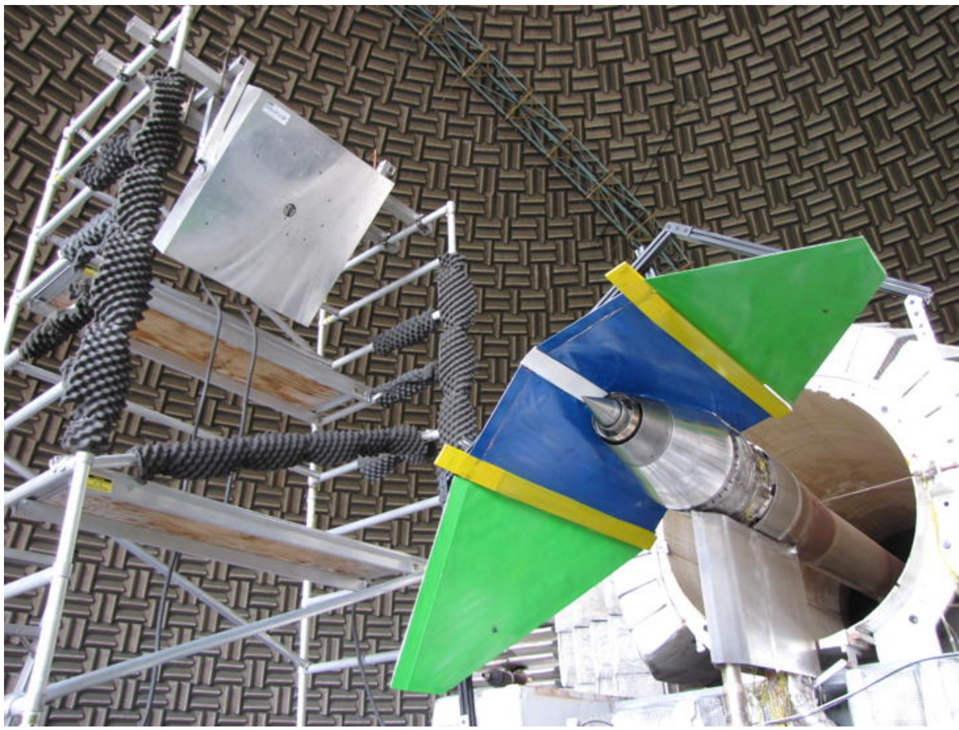


cycle	fanD	range
MFTF	8.177	4297.1
VCE	7.708	4241.4
VCE	7.685	4211.9

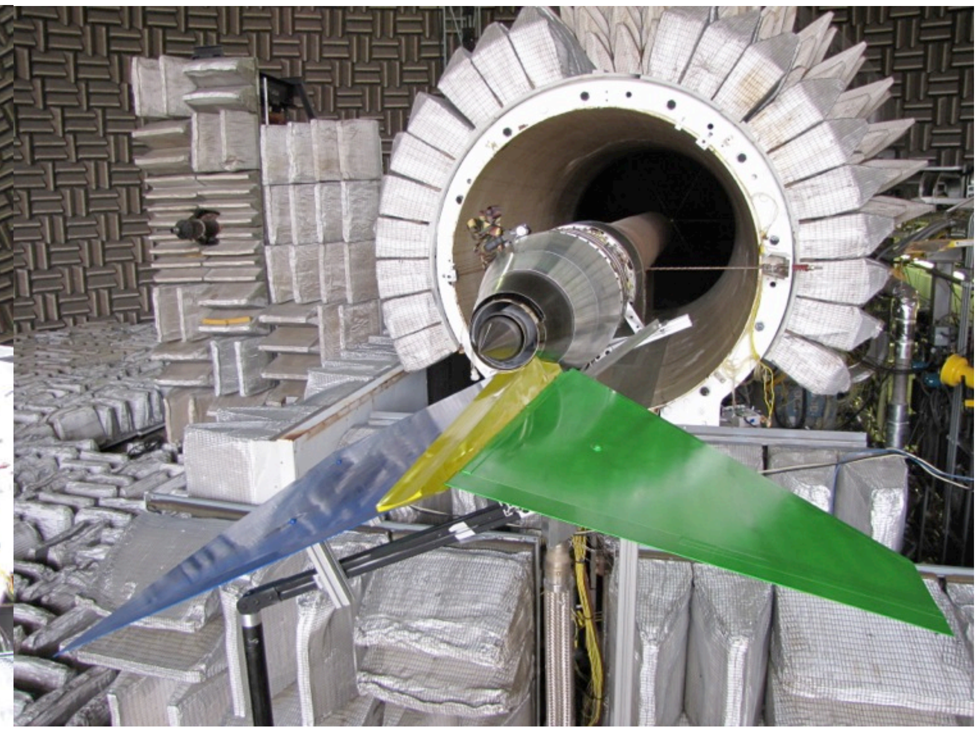
Demonstrated in Ground Test

- In 2015 a ‘static’ (no flight stream) test was conducted (JSI1044).
- Part of the test objective was to evaluate some critical aspects of the aircraft approximation.
  - How much of the vehicle has to be represented?
  - How many orientations must be measured?

Center Engine Configuration, 0° orientation



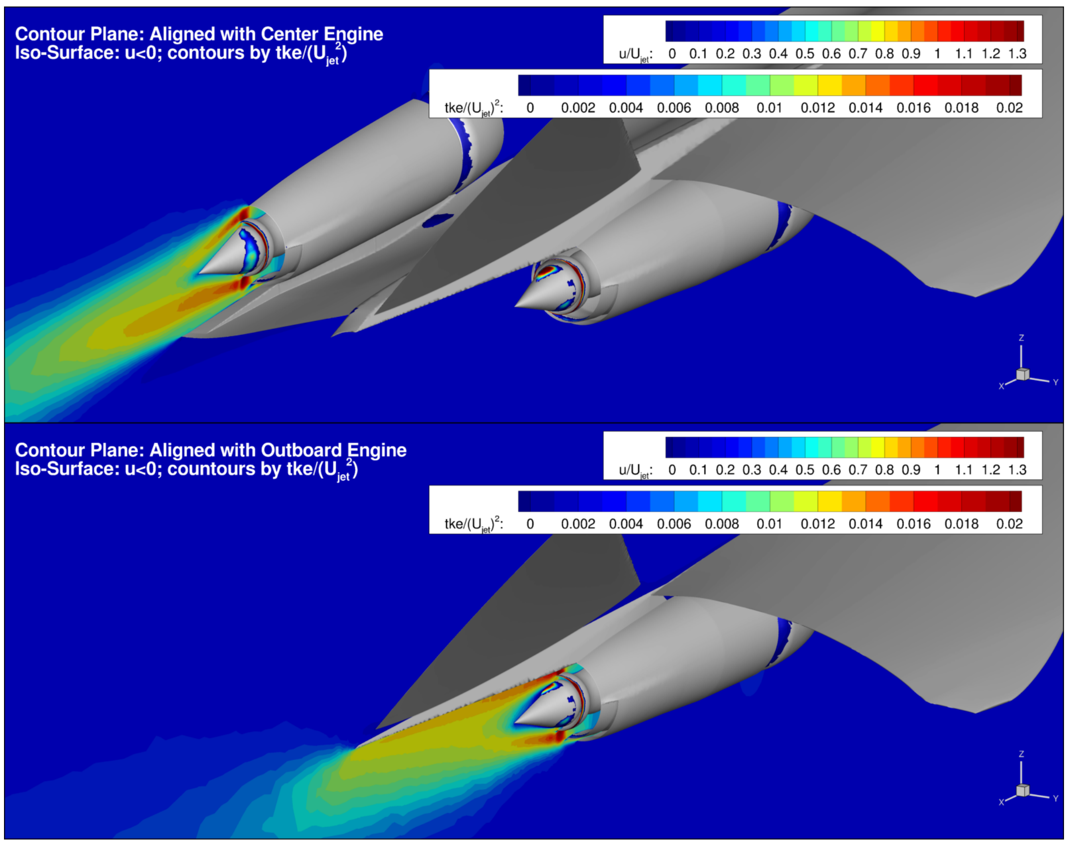
Outer Engine Configuration, 0° orientation



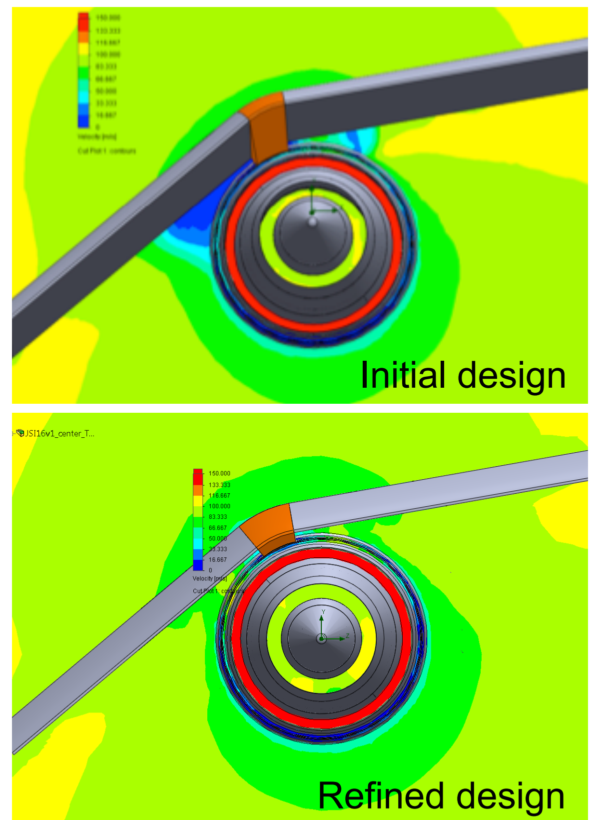
Matching flight stream for integrated propulsion on LM1044 vehicle

- Looking for
  - Disparities between nacelle diameter and jet rig diameter
  - Cross-stream flow from lifting body

CFD of full vehicle to characterize flow around nozzles

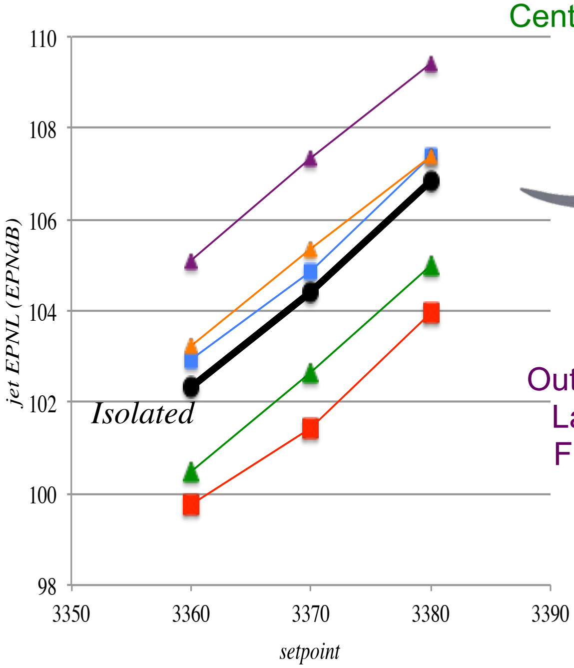


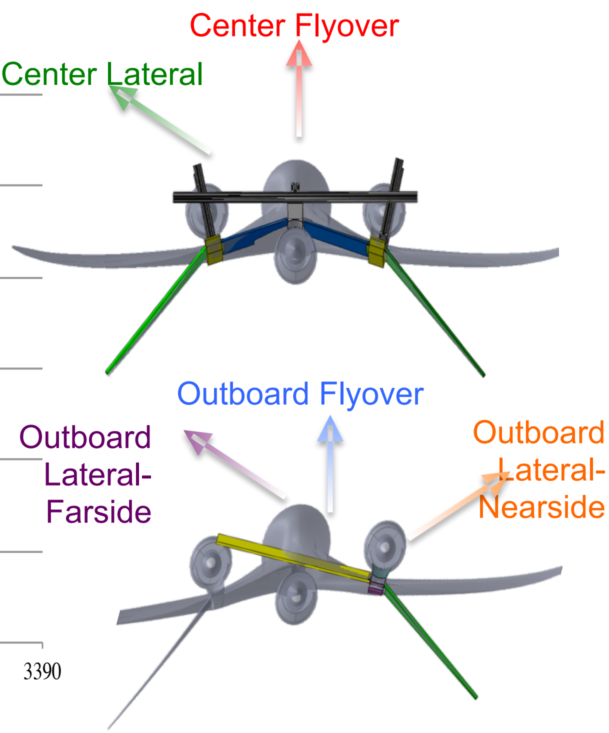
CFD of AAPL test article

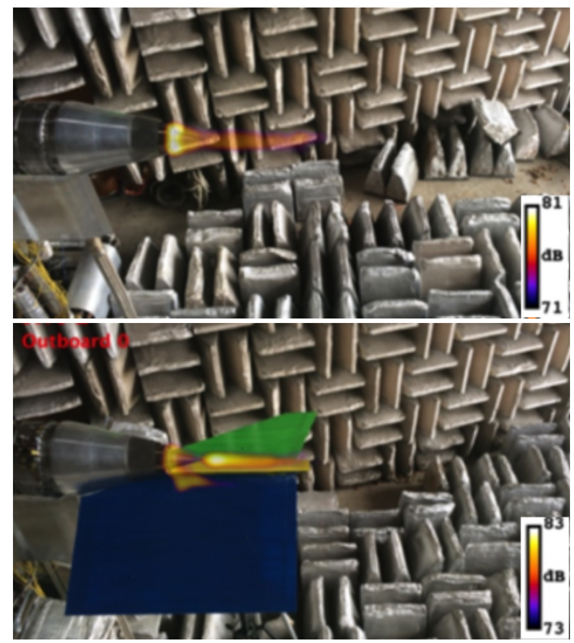


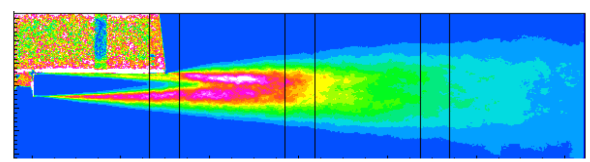
Integrated Propulsion Test

- Test deliverables
  - EPNL for all certification observers, multiple engine solutions, to confirm milestone deliverable
  - Phased array of noise source distributions, confirmation of shielding/reflection
  - PIV of turbulent flow to validate CFD









Looking Ahead

- Complete LNP Tech Challenge—Sept 2016
- New Tech Challenge for CST Airport Noise
  - New aircraft configurations
  - Consider all noise components in system studies
  - More computation, less experiment
- Continue system modeling to guide tech investment
- Possible technologies for focus
  - Inlet design for low noise fans with efficient cruise performance
  - Nozzle designs to complement topside engine mounting
  - Increased fidelity of predictions in system modeling
  - Improved test methods for integrated propulsion